

A RICH prototype for the AMS experiment

G. Boudoul, T. Thuillier, A. Barrau and M. Buénerd

ISN, 53 av des Martyrs, 38026 Grenoble, France

Abstract. The AMS spectrometer will be installed on the International Space Station at the end of 2003. Among other improvements over the first version of the instrument, a ring imaging Cherenkov detector (RICH) will be added which later should open a new window for cosmic-ray physics, allowing isotope separation up to $A \approx 25$ between 1 and 10 GeV/c and elements identification up to $Z \approx 25$ between threshold and 1 TeV/c/nucleon. It should also contribute to the high level of redundancy required for AMS and reject efficiency albedo particles. The results of the first generation prototype and the expected results of the new one are discussed.

1 Introduction

The AMS spectrometer (Buénerd M., (2000); Barrau A., (2001)) will be implemented on the International Space Station at the end of 2003 (or beginning of 2004). The instrument will be made of a superconducting magnet which inner volume will be mapped with a tracker consisting of 8 planes of silicon microstrips surrounded by a set of detectors for particle identification : scintillator hodoscopes, electromagnetic calorimeter (ECAL), transition radiation detector (TRD) and ring imaging Cherenkov (RICH). This contribution is devoted to a study prototype aiming at the RICH definition.

The physics capability of the RICH counter has been investigated by simulations (Buénerd, M. and Ren, Z. (2000)). It should provide unique informations among the AMS detectors by several respects :

- Isotopes separation up to $A \approx 25$ at best, over a momentum range extending from about 1-2 GeV/c up to around 13 GeV/c.
- Identification of chemical elements up to $Z \approx 25$ at best, up to approximately 1 TeV/nucleon.

- High efficiency rejection of albedo particles for momenta above the threshold, between 1 GeV/c and 3.5 GeV/c depending on the type of radiator ((Thuillier T., et al. , 2001a).
- High level of redundancy to provide high purity samples of positrons and antiprotons.
- Potential help in rejecting wrongly identified antimatter candidates for configurations similar to those found in antihelium search during phase I (AMS, 2000).

The RICH counter will allow to collect a unique sample of nuclear astrophysics data with unprecedented statistical significance over a momentum range totally unexplored for the most interesting isotopes.

Fig. 1 shows, as an example, the ^{10}Be to ^9Be ratio with 6 weeks of counting time (Bouchet A., et al. (2001)). Both the number of events and the covered energy range will dramatically improve the available data (lower left points on the plot).

Recent works (Maurin D., et al. (2001) ; Donato F., et al. (2001)) have emphasized the importance of measuring cosmic nuclei spectra for: 1) Setting strong constraints on the astrophysical and cosmic ray propagation parameters of the galaxy : the diffusion coefficient normalisation and its spectral index, the halo thickness, the Alfvén velocity and the convection velocity; 2) Increasing the sensitivity to new physics search for supersymmetric particles or primordial black holes; 3) Testing for the nature of the cosmic-ray sources : supernovae, stellar flares, Wolf-Rayet stars, etc ...

Equipped with a RICH counter, the AMS experiment will have the unique capability of being able to achieve the measurements of all the useful distributions with the same detector over the broadest range ever covered.

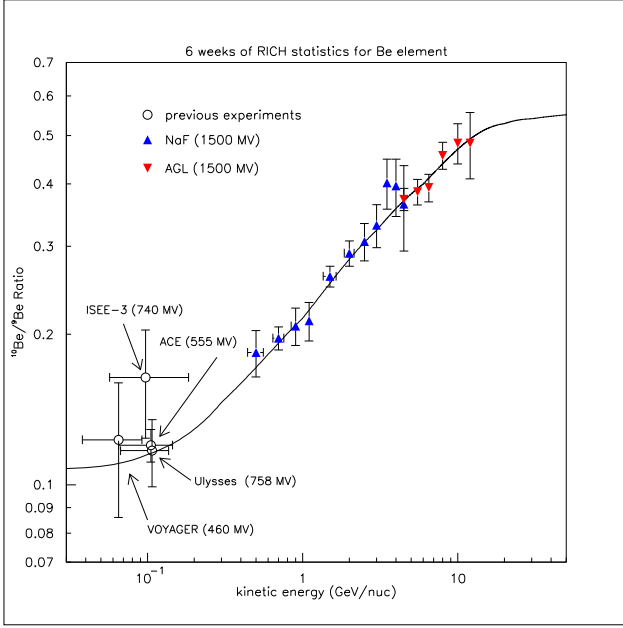


Fig. 1. Expected statistics for the ^{10}Be isotope for 6 weeks of counting with AMS (Bouchet A., et al. , 2001).

2 Study prototype

A first generation study prototype of the RICH counter has been developed and studied in Grenoble over the last few years (Thuillier T., et al. (2001b)). The instrument consisted of a matrix of 132 3/4" diameter Philips XP2802 photomultiplier tubes (PMT) available from a previous experiment. The size was compatible with the requirements provided by preliminary simulation results (Buénerd, M. and Ren, Z., 2000). The PMTs were equipped with a lime glass window (photon sensitivity range {280,640} nm). The tubes were mounted mechanically with individual magnetic shieldings on a support of aluminium drilled with appropriately spaced housing holes. Each PMT was mounted with a socket connected by a short cable to the front end electronics board placed behind the matrix. The counter was installed in a vacuum chamber equipped with a pumping system for vacuum tests. Two experimental configurations were used for cosmic ray and beam particle detection respectively.

In the two experimental setups used (cosmic-rays and accelerator beam), the prototype was complemented with a set of detectors (scintillators paddles, multiwire proportionnal chambers mwpcs) used to provide a trigger to the DAQ system, and to reconstruct the incident particle trajectory. Fig. 2 shows a picture of the installation. A set of radiators with refraction index from 1.025 (aerogel) up to 1.332 (sodium fluoride NaF) have been tested with different drift distances between radiator and detector plane, and different thickness.



Fig. 2. Photographic view of the experimental setup during cosmic ray tests, showing the PMT matrix placed inside the vacuum chamber, the tracker system (mwpcs) and the upper scintillator paddle installed on the chamber lid. The latter was moved with a crane.

2.1 Cosmic ray measurements

The setup has been operated for more than a year. The results are illustrated on figure 3. The best experimental velocity resolution obtained for cosmic ray test was $\frac{\delta\beta}{\beta} = 0.9 \times 10^{-2}$ with $\bar{n} = 1.33$ NaF radiator (Cherenkov threshold around 480 MeV/nucleon), and $\frac{\delta\beta}{\beta} = 5.2 \times 10^{-3}$ with $\bar{n} = 1.035$ aerogel radiator (Cherenkov threshold around 3.5 GeV/nucleon). These resolutions were limited by the size of the photodetectors, in particular for the aerogel radiator which expected best resolution is about 10^{-3} . The study has shown that: a) The radiator thickness and refractive index combinations for the final version of the counter must be optimized carefully to match Physics program; b) This technique of proximity-focused ring imaging Cherenkov counter allows velocity resolutions compatible with the AMS physics purpose; and c) The good agreement between data and simulation gives confidence in the latter and then in the simulated performances expected for the final AMS RICH.

2.2 In beam measurements

The prototype has also been tested at the GSI / Darmstadt ion accelerator facility with ^{12}C beams of 0.6, 0.8, 1, 1.2, and

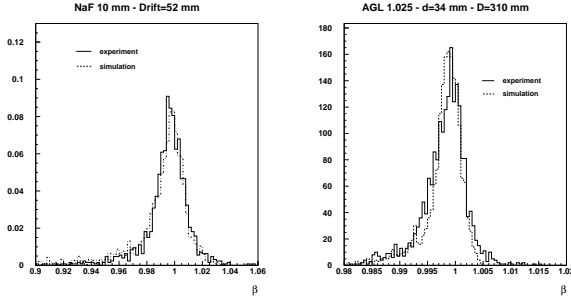


Fig. 3. Sample of cosmic test results. The experimental velocity distribution of CR (full line histogram) is compared with simulation results (dashed) for NaF (left) and aerogel (right) radiators.

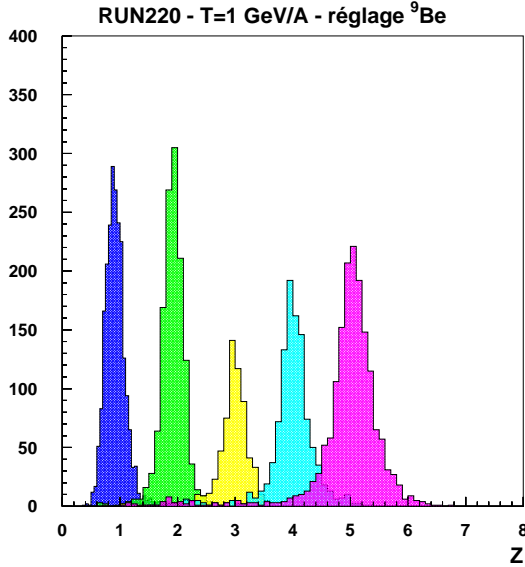


Fig. 4. Experimental Z reconstruction obtained with a ^{12}C ion beam at $T = 1 \text{ GeV/A}$.

1.4 GeV/nucleon incident energies. Figure 4 shows the reconstructed charge of particles for 1 GeV per nucleon beam. Beam particles with different masses were obtained by using a fragmentation target. Only the NaF radiator could be tested in this experiment since the maximum beam velocity of the accelerator was below the threshold for the aerogel radiators considered.

3 Second generation prototype

The second generation prototype has been developed by the RICH group¹ of laboratories of the AMS collaboration. It will consist of one module of the final counter and will be operated during the second half of the year 2001.

¹AMS RICH group: INFN Bologna, U. Florida, ISN Grenoble, LIP Lisbon, CIEMAT Madrid, U. Maryland, and UNAM Mexico

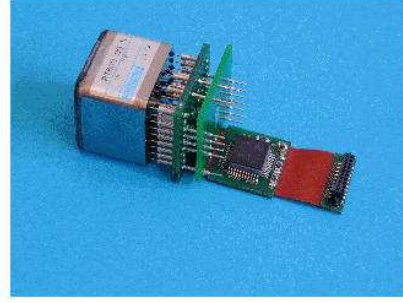


Fig. 5. R5900-M16 PMT connected to the front-end electronics

The counter will be equipped with R7900-M16 PMTs from Hamamatsu Inc. (one hundred units in the prototype). The R7900-M16 is a space qualified 16 pixels PMT ($16 \times (4 \times 4 \text{ mm}^2)$) with 12 metal channel dynodes and a borosilicate glass window. The high voltage divider used is a compromise between single photoelectron resolution ($\frac{\sigma}{Q} \approx 0.5$) and linearity (90% at 100 photoelectrons). The front-end electronics (Gallin-Martel L., et al., 2001) will be placed next to the PMT on a flex connector linked to the readout bus (Fig. 5). Each PMT will be equipped with solid light guides to collect the Cherenkov photons and to reduce the dead-space between photocathodes. Prototype II will be installed in the same instrumental setup as the previous version and read with the same DAQ system.

The main goals of this new generation of prototype are: Validation of the complex assembly procedure, validation of the readout electronics settings and DAQ procedure for the 16000 output channels, investigation of the PMT+electronics response dynamics, measurement of the counter velocity resolution, testing the whole structure against vibrations, and validation of the magnetic shielding efficiency.

4 Conclusion

A study prototype of proximity focused RICH has been built and studied. The results have been found in good agreement with the simulation results. The performances should be improved with the next generation prototype (in account of the 3 times small pixel size) and reach the nominal limits of the counter. The latter is now under construction and should be the first step to the final counter assembly.

Acknowledgements. The authors are heavily indebted to the engineering team of the ISN Grenoble: J. Ballon, G. Barbier, R. Blanc, L. Gallin-Martel, J. Pouxe, O. Rossetto, J.P. Scordilis, and C. Vescovi for their unvaluable help and support in the design, assembly and operation of the prototype.

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